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Interactive management control via analytic hierarchy process (AHP). An empirical study in a public university hospital

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Abstract: Management control in public university hospitals is a challenging task because of continuous changes due to external pressures (e.g. economic pressures, stakeholder focuses and scientific progress) and internal complexities (top management turnover, shared leadership, technological evolution, and researcher oriented mission). Interactive budgeting contributed to improving vertical and horizontal communication between hospital and stakeholders and between different organizational levels. This paper describes an application of Analytic Hierarchy Process (AHP) to enhance interactive budgeting in one of the biggest public university hospital in Italy. AHP improved budget allocation facilitating elicitation and formalization of units' needs. Furthermore, AHP facilitated vertical communication among manager and stakeholders, as it allowed multilevel hierarchical representation of hospital needs, and horizontal communication among staff of the same hospital, as it allowed units' need prioritization and standardization, with a scientific multi-criteria approach, without using complex mathematics. Finally, AHP allowed traceability of a complex decision making processes (as budget allocation), this aspect being of paramount importance in public sectors, where managers are called to respond to many different stakeholders about their choices.

Keywords: analytic hierarchy process, budget, interactive budgeting, management control, accounts management.

1. INTRODUCTION

Although "management" and "control" are words used in a broad sense, "management control" (MC) is recognized as a pragmatic approach, which leads an organization to achieve goals through a structured process, measuring activities of units and workers to improve constantly organization efficiency and effectiveness. According to Anthony and Young *management control is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives.*

A major feature of most MC systems is the budged allocation process. Budgeting systems are used by top management as a mean of coordinating and communicating strategic priorities and, in conjunction with reward systems, are often used to facilitate lower-level managers' commitment to these priorities. According to the classification of budget systems proposed by Simon (1987), there are two main approaches to MC: diagnostic or interactive. In the former, budget is used to evaluate performance and attributing responsibility. In the latter, budgets can also be used as a dialogic process to learn and facilitate creation and diffusion of new ideas. Diagnostic budget mainly requires vertical communication among top management and subalterns. Interactive budget also requires lateral communication among managers of different units, across levels and functions. In fact, a distinctive feature of interactive use of budgets is the continual exchange between top management and lower levels of management, as well as interactions within various levels of management across functions.

This leads account managers to adopt scientific *methods to facilitate this communication* (Abernethy and Brownell, 1999). Moreover, public organizations are pushed to change under the pressure of systemic threads and challenges. This is the case of hospitals today, under the big pressure of global economic crisis. Changing process creates a context where decision making by top management becomes increasingly complex and unpredictable as new opportunities alter strategic objectives, or change their priorities. Therefore, *methods to allocate budget should provide elasticity and a clear system of prioritization*. Furthermore, although hospital hierarchy exists, it is difficult to talk about subordinates and superiors, and medical doctors in operative units have at least the same weight as top managers in the steering to budget allocation process. This complicates also the leadership, requiring the adoption of *methods to facilitate consensus finding* (Abernethy, Bouwens et al., 2010).

Additionally, in democratic countries, in which the healthcare organizations are totally or partially supported by the public funds, hospital managers are ultimately responsible for the citizens regarding their decisions (Rosanas and Velilla, 2005). This requires the adoption of *methods, which allow stakeholder not skilled in complex mathematics, to understand the reasons of decisions*. On the other hand, the use of sc*ientific quantitative methods to support decision making* is considered necessary in healthcare organizations, where the personnel are committed to follow only the best available evidence according to well-designed trials (Bracale, Rovani et al., 2012b), meta-analyses (Bracale, Rovani et al., 2011) or network meta-analyses (Bracale, Rovani et al., 2012a). In this study, we proposed the use of Analytic Hierarchy Process (AHP) as a method for budget negotiation within the context of a university hospital(Iadanza, Dori et al., 2009, Miniati, Dori et al., 2011a, Miniati, Dori et al., 2011b) to support interactive MC. AHP is a scientific decision making method, based on the idea that it is possible to prioritize factors affecting a decision by: grouping them into meaningful categories and sub-categories; performing pairwise comparisons; defining a coherent framework of quantitative and qualitative knowledge, measuring also intangible domains. Several methods were proposed to enhance MC (Gil, 2010) (Naranjo-Gil, 2009), organization and planning (Grafton, Abernethy et al., 2011), and to measure productivity (Chang, Hsiao et al., 2011), performance (Grigoroudis, Orfanoudaki et al., 2012) and quality (Buyukozkan and Cifci, 2011). AHP was chosen in this study because: it is multilevel, facilitating vertical communication of strategies and objectives; it is multidimensional and multi-factorial, facilitating inter-disciplinary communication among units' managers with different specializations; it uses no complex mathematical methods to represent decision maker's needs, facilitating communication with stakeholders (politics and citizen) which may be not skilled in complex mathematics (Bruno, Esposito et al.). AHP was previously used to strategic planning (Partovi, 2006), for group decision-making under fuzzy environments (Hatami-Marbini and Tavana, 2011), for revenue management process under uncertainty (Tsai and Hung, 2009). A number of articles have highlighted the benefits of AHP use in healthcare (Liberatore and Nydick, 2008), , because of its multidimensional and multi-criteria nature(Pecchia, Bracale et al., 2009) and because is considered to be easy to use and time-saving (Chatburn, 2001). As far as author knowledge, no previous studies applied AHP for budget allocation and MC in a university hospital.

In this article, we present the results of an application of AHP to support the MC in one of the bigger Italian university hospital.

2. METHODS

AHP is a multi-dimensional, multi-level and multifactorial decision-making method based on the idea that it is possible to prioritize factors by: grouping them into meaningful categories; performing pairwise comparisons among factors; defining a coherent framework of quantitative and qualitative knowledge, measuring also intangible domains.

2.1 Hierarchy definition and questionnaires

Once interviewed managers and medical doctors in charge of complex units of the University Hospital Federico II of Naples, factors influencing budget allocation in previous years were identified. These factors were then organized in uniform categories and subcategories. Finally a tree of factors was designed, in which each node represented a category, each sub-node represented a subcategory and each leaf represented a factor. In order to elicit how important it was to invest in each factor into each subcategory, questionnaires were designed to ask each respondent to compare the relative importance of each factor with all the other into its subcategory. In these questionnaires, for each pair of factors (*i,j*), responders were asked the following question: "in accordance with the situation in your unit, how important do you consider to invest in the *factor i* compared to the *factor j*?". Responders answered choosing one of the following judgments: much less, less, equally, more, or much more important. In accordance with the natural scale by Saaty (1977), an integer numerical value was given to each judgment as following, i.e. 1 if equally, 3 if more important. The reciprocal values were given to the remaining judgments. The process was then iterated, designing similar questionnaires to elicit the relative importance of each subcategory and each category.

2.2 Judgment matrix

For each subcategory of factors, a judgment matrix A_{nxn} was designed, where "*n*" is the number of factors in this subcategory. Each matrix had the following proprieties:

1) the generic element (aij) referred to the ratio between the relative importance of the factor "i" (Fi) and "j" (Fj);
2) the element aji was the reciprocal of aij, assuming the reciprocity of judgment (if invest in Fi was 3 times more important than invest on Fj, then Fj should be 1/3 of Fi);
3) the elements aii was equal to 1;
4) by definition of aij (1), the matrix A is assumed to be a transitive matrix, which means that „$\forall\ i, j, k \in (1\,; n),\ a_{ij} = a_{ik} * a_{kj}$„

$$a_{ij} = \frac{F_i}{F_j} = \frac{F_i}{F_k} * \frac{F_k}{F_j} = a_{ik} * a_{kj} \quad (1)$$

This last propriety is called transitivity property and reflects the idea that if investing in "i" was considered twice more important than investing in j ($F_i = a_{ij} * F_j$), and investing in "j" was considered three time more important than "k" ($F_j = a_{jk} * F_k$), then investing in "i" should be judged six time (two time three) more important than investing in "k" ($F_i = a_{ik} * F_k$, with $a_{ik}=a_{ij}*a_{jk}$).

2.3 Relative importance of factors into each subcategory

It has been proved (Saaty, 1977) that, if a matrix A respected these properties then each column was proportional to the other and only one real eigenvalue (λ) existed, which was equal to "n". The corresponding eigenvector was again proportional to each column and its components, which normalized, represented the relative importance of investing in each factor, compared to the other in the same subcategory. The relative importance (weight) of a factor i into the category k will be further recalled as FW_i^k or local weight. In case the judgments were not fully consistent, the columns of the matrix were not proportional. In this case the matrix had more eigenvectors and none proportional to all the columns. In this case, the main eigenvector, which is the one corresponding to the eigenvalue (λ_{max}) bigger in module, was chosen. Its normalized components represented the relative importance of each factor.

2.4 Consistency estimation

If the transitivity propriety is not respected, an inconsistency is generated. This inconsistency can be estimated by posing some redundant questions. Considering three factors (i, j, and k) the respondent was asked to perform the pair comparisons i-j and j-k, and then the redundant comparison i-k. The answer to the redundant question was compared with the one deduced from the first two, assuming the transitivity of judgment. The difference between the real answer and the transitive one represents the degree of inconsistency. Mathematically, the inconsistency of each response was modelled as an error: $error_{ij}=a_{ij}-a_{ik}*a_{kj}$. The global effect of these errors on the judgment matrices was estimated measuring the difference of the major eigenvalue λ_{max} from "n". This inconsistence is in the majority of cases due to the loss of interest or to distractions. However, the scale of natural numbers adopted cause some systemic inconsistencies because not all the ratio could be represented and because of limited upper value. For this reason, an error less than a certain threshold was accepted in accordance to literature (Pecchia, Bath et al., 2011).

2.5 Importance of factors, sub-categories and categories

By applying the same algorithm to sub-categories, it was possible to evaluate their relative importance within their categories. The relative importance of a subcategory k into a category m will be further recalled as SCW^{km} or local importance of subcategory. The same was done between categories and the relative importance of a category m will be further recalled as CW^m.

Finally, the relative importance of a factor i compared to the others in the same category m (across sub-categories) is defined as meso-importance (meso-weight) of the factor i into the category m (MW_i^m). In other words, the meso-weight (meso- is a suffix word, widely used in medicine, indicating an intermediate level) will allow to compare the relative importance of each factor with all the other falling in the same category, although in different sub-categories. The relative importance of the factor i compared the all the other (across categories and sub-categories) is defined as global importance (global weight, GW) of the factor i. Both are calculated by multiplying the local importance of the factor per the one of the root element into the Hierarchy. For instance the meso-weigth of the factor i into the category m is calculated as the product of the local importance (weight) of the factor (LW_i^k) per the importance (weight) of its subcategory into the category m (SCW^{km}) (2).

$$MW_i^m = SCW^{km} * FW_i^k \quad (2)$$

Similarly, the global importance of the factor i (GW_i), which is in the subcategory k, and is an element of category m, is calculated as following:

$$GW_i = CW^m * MW_i^m \quad (3)$$

Finally, also sub-categories have a global importance ($GSCW$) as shown in (4).

$$GSCW^k = CW^m * SCW^k \quad (4)$$

2.7 Judgment pooling

The previous steps produced a set of judgments for each element of the hierarchy and a set of matrices for each respondent as listed below: a matrix per each subcategory, containing pairwise comparisons on factors within the subcategory; a matrix per each category, containing pairwise comparisons on sub-categories within the category; a matrix containing pairwise comparisons on categories.

Following a well assessed method for group decisions making, individuals' opinions were integrated, by applying the geometric mean (Basak and Saaty, 1993) among respondents' judgment matrices. After this averaging process, for each subcategory and category, there was just one matrix, which reflects the average opinion of all the respondents. The geometric mean preserves transitivity by definition, as reported in (5).

$$\bar{a}_{ij} = \sqrt[m]{\prod_{z=1}^{m} a_{ij}^z} = \sqrt[m]{\prod_{z=1}^{m} a_{ik}^z * a_{kj}^z} = \sqrt[m]{\prod_{Z=1}^{m} a_{ik}^z} * \sqrt[m]{\prod_{z=1}^{m} a_{kj}^z} = \bar{a}_{ik} * \bar{a}_{kj} \quad (5)$$

The outcome of this step was a set of averaged consistent judgment matrices. From each averaged matrix, the main eigenvector was calculated and its normalized components represented the pooled importance of each judged element.

3. RESULTS

In collaboration with 3 managers and 3 medical doctors of the hospital, a hierarchy of 27 factors, grouped into 9 sub-categories and 3 categories was designed (Fig. 1).

13 questionnaires, composed by three questions each, was designed and piloted in lab: 9 questionnaires (one per each subcategory) to elicit local importance of factors; 3 questionnaires (one per each category) to elicit relative importance of each subcategory into each category; 1 questionnaire to elicit relative importance of each category of factors. Fig. 2 shows the questionnaires developed. To reduce word confusion and to avoid mistakes, 9 independent responders piloted the questionnaire. Finally, 7 medical doctors in charge of 7 different medical units, was randomly chosen among the 62 units of the case study hospital, answered the questionnaires. All the responders answered consistently all the questionnaires. Therefore, the results based on the relative importance of categories, pooled among the 7 final responders, are presented in the Table 1.

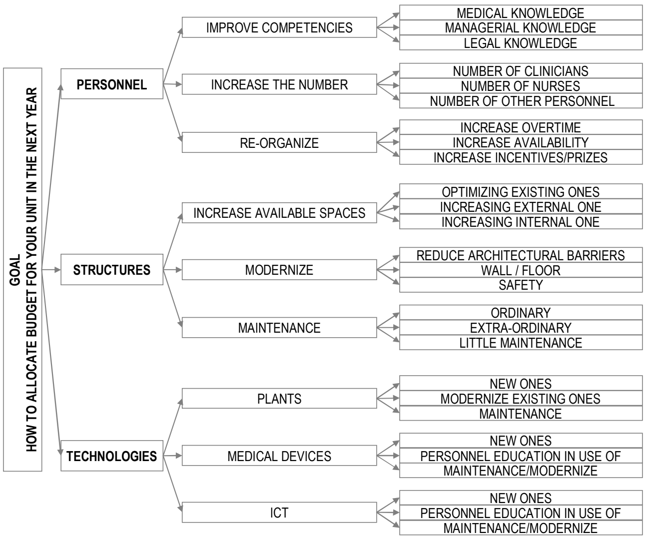

Fig. 1. Hierarchy.

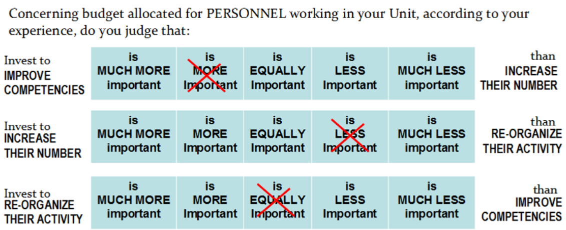

Fig. 2. Questionnaires

In the last column, the weights were normalized to the minimum weight (in this case "structure"). This index allowed us to easily communicate the results to decision makers not skilled in mathematical methods. Table 1 presented also the averaged judgment matrix (second, third and fourth columns). This was useful to understand the final weights. For instance, the first row of the judgment matrix, demonstrated that investing in personnel was considered respectively 2.8 and 2.5 times more important than investing in structures of technologies, while investing in structure was considered .7 times important than investing in technologies. This explained why personnel is considered almost 3 times more important than investing in structures and the final prioritization of relative importance of investing in different categories of factors: first in personnel, second in technologies and then in structures. The local and the global relative importance of sub-categories, pooled among responders are reported in Table 2.

Table 1. Relative importance of categories

Categories	Judgement matrices			Weight	
PERSONNEL	1.0	2.8	2.5	.55	2.95
STRUCTURE	.3	1.0	.7	.19	1.00
TECHNOLOGIES	.4	1.4	1.0	.27	1.43

Also the sub-categorical weights were normalized to the minimum to facilitate communication. For instance, regarding subcategory of factors concerning personnel, recruiting new members' staff was considered twice important than reorganizing their activities. Recruiting new members was also considered the most important action to do for the next year. In fact, this was scored six times more important than increment spaces, which was considered the last important one.

Table 2. Relative importance of sub-categories.

Categories and sub-categories	Judgement matrices			Local* Weights		Global* Weights	
PERSONNEL							
Improve competences	1.0	.6	1.3	.29	**1.26**	.16	**3.85**
Increase number	1.6	1.0	2.0	.48	**2.04**	.26	**6.24**
Activity reorganization	.8	.5	1.0	.23	**1.00**	.13	**3.06**
STRUCTURE							
Spaces Increment	1.0	.5	.8	.23	**1.00**	.04	**1.00**
Structure modernization	2	1.0	1.6	.48	**2.04**	.09	**2.04**
Structure maintenance	1.3	.6	1.0	.29	**1.26**	.05	**1.26**
TECHNOLOGIES							
Technological Plants	1.0	1.0	.4	.18	**1.00**	.05	**1.50**
Biomedical Technologies	2.7	2.8	1.0	.48	**2.67**	.13	**4.00**
Information & Communication Tec. ICT	2.0	2.0	.7	.34	**1.89**	.09	**2.83**

The relative weights of each individual factor were estimated too. Because of the limited number of pages, only the importance of the most important factors are reported and discussed in the discussion session.

4. DISCUSSION

In this article, we presented a method to elicit the needs of complex units at a University public Hospital, following a traceable bottom-up approach of budget allocation. The hierarchy proposed reflected the structure of National and Regional regulations on minimum requirement for structure offering healthcare services, both public and private (2001). To enable responders to familiarize themselves with the terminology and with the hierarchy, firstly we submitted questionnaires comparing factors and then those comparing sub-categories. Therefore, the respondent knew what was included in each subcategory. For the same reasons, all the questionnaires comparing sub-categories, were submitted before the one comparing categories. The responders, which represent the 11.3% of all the unit of the hospital, did not report difficulty with the questionnaires, and were extremely satisfied with the method. In particular, all have confirmed that the findings presented accurately reflected the needs of their units. Moreover, 6 of the 7 spontaneously stated that they would not be as effective in expressing their needs without this method. In addition, the timing of the questionnaire was considered satisfactory. In the last 5 years, the budged negotiation has required more meetings each of them taking at least two hours. The questionnaire took about 30 minutes (28±9) to be completed consistently. The results of the questionnaires facilitated the communication with elicitors. Accounting Managers reported the highest satisfaction about the adoption of the method and the intention to extend the experimentation of the method to all units next year, since the budget negotiation runs each year from October to November. The top management of the hospital has declared the maximum interest in this methodology especially to indicate convergences and divergences between the strategic objectives of the hospital and the needs of individual units. Finally, the results of this study were utilized by the Hospital top management to discuss, politically, divergences between Regional strategic goals (and regional budget allocation) and local needs. All the experts involved in the study were satisfied for the limited use of mathematics and for the easiness to communicate achieved results. Finally, the quantification of units' needs facilitated lateral communication and the achievement of consensus. Regarding the prioritization of factors, sub-categories and categories for budget allocation, the results presented reflect the main problems of the Hospital. The principal need that emerged was to invest in personnel. Particularly, it was required to enrol new staffs, which was scored first for global weight over the 9 sub-categories, especially non-medical auxiliary personnel (scored first over 27 factors). This reflects the fact that the programmed recruiting of new non-medical staff is blocked by more than 10 years for economic constrains. Consequently, in 2011, the mean age of employed personnel into the hospital (2,237 employees) was 53.71 years old (range from 29 to 72 years old). The age of employees per function, reflected responders' judgment. Concerning employed personnel, the main requirement was to improve competences (3rd among sub-categories), especially managerial competences (scored second among all factors) to diffuse the culture of affordability and appropriateness. This reflected the fact that, since 2007, responsible for the hospital (any level) were under the pressure of an austere economic recovery plan (2007), a blueprint for a return to sustainable healthcare services, which was imposed by the Ministry of Health to reduce the deficit of the INHS in Campania Region, where the Hospital is located. In the main time, doctors in charge of units proposed to compensate the limited number of staff by reorganizing their activities (4th among the 9 sub-categories), or promoting systems of incentives (7th among factors) to increase the productivity of personnel. Among sub-categories, the second request for global weight was to invest in medical devices, especially to purchase new ones. Although this result could be the same in many hospitals, due to the continuous evolution and importance of medical device to improve the quality of care, this consideration reflects locally the mission of the hospital aimed at research and healthcare. Moreover, the method presented is traceable. For instance, it is possible to demonstrate that 'increase external spaces' was considered the less important among all the factors (GW=.01), because it was scored as less important into the subcategory of 'increment spaces' (LW=.17), which was scored the less important among subcategory felt in category called 'structure' (SCW=.23), which was scored the less important among categories (CW=.19). This is essential in a public no profit organization of a democratic country, where the national health services is fully supported by public funds. Regarding the methods, we adapted the AHP to the specific case in which it is used with responders not experienced in its use. These adaptation are discussed in detail in a recent paper (Pecchia and Morgan, 2013), freely available online. The application of AHP to elicit the needs of healthcare professionals can be found in the references (Pecchia, Martin et al., 2013a, Pecchia, Martin et al., 2013b).

AHP fulfilled the needs of the hospital managers as it meets 5 requirements of decision making, which are fundamental in medicine:

5) to *facilitate the communication (horizontal and vertical, internal and external)*;
6) to be *elastic*, *transparent and traceable of prioritization*
7) to simplifying the achievement of *consensus*
8) to allowed the involvement of stakeholders not *skilled in complex mathematics*
9) to use a *scientific (and elegant) approach* as required by medical doctors that are committed to the use of evidence based medicine.

5. CONCLUSIONS

The method proposed enabled eliciting analytically the needs of doctors in charge of units responsible for budget negotiation. The elicitation process was traceable, multilevel and fully intelligible, reflecting the needs of interactive management control systems in a public university hospital, ad facilitating vertical and horizontal communications. In fact, AHP supported accounting managers in: negotiating budgets, proving the reasons of their choices (also after years); communicating their options at any required level (medical doctors, top management, politicians, public opinion); ensuring maximum transparency of decision-making processes that impact on the allocation of the budget; finding consensus facilitating lateral communication. AHP supported clinicians in charge of hospital units to express and formalize their needs. Moreover, all the clinician needs were standardized improving horizontal communication among units. The overall process of budget negotiation was improved and accelerated.

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